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Recruitment, Growth and Condition of a Population of the White Sucker, *Catostomus commersoni*, in Lake 223, an Experimentally Acidified Lake

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RECRUITMENT, GROWTH AND CONDITION OF A POPULATION OF THE WHITE SUCKER, *Catostomus commersoni*, IN LAKE 223, AN EXPERIMENTALLY ACIDIFIED LAKE

by

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TABLE OF CONTENTS

	Page
ABSTRACT/RESUME	iv
INTRODUCTION	1
MATERIALS AND METHODS	1
RESULTS AND DISCUSSION	2
Recruitment	2
Growth	2
Condition	3
Summary	4
ACKNOWLEDGMENTS	4
REFERENCES	4
TABLE 1. Mean condition factors ±95 % confidence limits at annual spring intervals from 1976-1983 for nine fork-length groups	6

LIST OF FIGURES

Figure	Page
1a. Length-frequency histograms on a seasonal basis from fall 1975 until fall 1980	7
1b. Length-frequency histograms on a seasonal basis from spring 1981 until fall 1983	8
2. Numbers of young-of-the-year white suckers captured on a monthly basis (June - October) from 1977 until 1983.	9
3. Composite age-frequency histogram for 1976, showing corresponding year-classes	10
4. Summary of growth curves of white suckers, based on fork lengths at annual spring intervals	11
5. Growth curves of white suckers, based on back-calculated fork lengths, at annual spring intervals from 1971 until 1975 compared to growth curves since 1976	12
6a. Growth curves of white suckers, based on fork lengths, on a seasonal basis from fall 1975 until fall 1979	13
6b. Growth curves of white suckers, based on fork lengths, on a seasonal basis from spring 1980 until fall 1982	14
7a. Growth curves of white suckers, based on weights, on a seasonal basis from fall 1975 until fall 1979	15
7b. Growth curves of white suckers, based on weights, on a seasonal basis from spring 1980 until fall 1982	16
8a. Comparisons of growth curves of white suckers, based on fork lengths, for males and for females at annual spring intervals from spring 1978 until spring 1982	17
8b. Comparisons of growth curves of white suckers, based on weights, for males and for females at annual spring intervals from spring 1978 until spring 1982	17
9a. Condition factors of white suckers at seasonal intervals from fall 1975 until fall 1983	18
9b. Condition factors of white suckers at spring intervals from 1976 until 1983	18

ABSTRACT

Chalanchuk, S. 1985. Recruitment, growth, and condition of a population of the white sucker, Catostomus commersoni, in Lake 223, an experimentally acidified lake. Can. Tech. Rep. Fish. Aquat. Sci. 1396: iv + 18 p.

A population of the white sucker, Catostomus commersoni, in Lake 223, in the Experimental Lakes Area, northwestern Ontario was studied from 1975 until 1983 to monitor the responses of the fish to experimental acidification of the lake. Recruitment failures occurred in 1981, 1982 and 1983 when the pH of the lake was between 5.0-5.2. Normal recruitment occurred in this lake in all other years from 1971-1980 when the pH was between 5.6-6.5, and in other non-acidic lakes in this area during 1971-1983. Growth of fish aged two to six years increased as lake pH decreased from 6.5 to 5.5. Condition factors of all fish initially increased. These increases in growth and condition were made possible by increasing food supplies. By 1981-1982, when Lake 223's pH was 5.02, a decrease in food supply coincident with a peak in abundance of white suckers led to a decline in condition factors and a slight decline in growth of fish aged two to six years. Lowest condition factors occurred in 1983.

Key words: Sucker, white; pH; growth; recruitment; condition.

RESUME

Chalanchuk, S. 1985. Recruitment, growth, and condition of a population of the white sucker, Catostomus commersoni, in Lake 223, an experimentally acidified lake. Can. Tech. Rep. Fish. Aquat. Sci. 1396: iv + 18 p.

De 1975 à 1983, on a procédé à l'étude d'une population de meuniers noirs, Catostomus commersoni, dans le lac n^{o} 223 de la Région des Lacs Expérimentaux du nord-ouest de l'Ontario, afin d'évaluer les réactions du poisson à l'acidification expérimentale du lac. Les chercheurs ont constaté des échecs de recrutement en 1981, 1982 et 1983, lorsque le pH du lac se situait entre 5,0 et 5,2. Un recrutement normal est survenu dans ce lac pendant toutes les autres années de la période comprise entre 1971 et 1980, au moment où le pH était entre 5,6 et 6,5, ainsi que dans d'autres lacs non acidifiés de la région pendant la période de 1971 à 1983. La croissance des poissons âgés de deux à six ans a fait une progression lorsque le pH du lac est passé de 6,5 à 5,5. Les coefficients d'état de tous les poissons étudiés ont augmenté. Ces hausses de la croissance et de l'état ont été atteintes en augmentant l'approvisionnement en nourriture. En 1981-1982, au moment où le pH du lac 223 était à 5,02, une baisse de l'approvisionnement en nourriture couplée à l'abondance cyclique de la population a entraîné une chute des coefficients d'état et un léger ralentissement de la croissance des poissons âgés de deux à six ans. Les plus bas coefficients d'état ont été observés en 1983.

Mots-clés: meunier noir; pH; croissance; recrutement; coefficient d'état.

INTRODUCTION

The purpose of this study was to examine recruitment, growth and condition of a population of the white sucker, Catostomus commersoni, in response to experimental acidification of Lake 223, in the Experimental Lakes Area, northwestern Ontario.

The phenomenon of acid precipitation has been documented since the eighteenth century, although the environmental consequences of increased acidity only began to be understood much later (Cowling 1982). Various researchers have recently summarized the effects of low pH on aquatic organisms and ecosystems (Drablos and Tollan 1980; Singer 1981; Haines 1981). The loss of fish populations as a result of increasing acidification of lakes is well known (Beamish and Harvey 1972; Jensen and Snekvik 1972), but more information is needed about the causes of these losses. Physiological mechanisms such as failures in body salt regulation and in normal gill function (Muniz and Leivestad 1980; Leivestad 1982) are implicated in fish death during episodes of high acidity, such as spring run-off. This is especially true if metal contamination is also present. Extinction of fish populations, however, is usually attributed to recruitment failures. These can be caused by failure of females to release ova, hatching failure or embryonic mortality (Mount 1973; Beamish 1976; Schofield 1976; Peterson et al. 1980; Peterson et al. 1982).

Much of the data documenting pH effects on fish have been derived either from laboratory studies in which conditions may differ from natural situations or from observational studies of presence/absence of species in lakes at varying pH values. These studies may indicate threshold levels of toxic pH effects but not the mechanisms responsible for losses of fish populations at these pH values. The initiation of a whole-lake acidification experiment in Lake 223 provided an opportunity for extensive monitoring of the responses of a population of white suckers to decreases in pH in a natural ecosystem.

This report presents data on the recruitment, growth and condition of the white sucker population in Lake 223 and discusses the changes that occurred in response to decreases in pH.

MATERIALS AND METHODS

Lake 223 is a small oligotrophic lake (area = 27.3 ha, mean depth = 7.2 m) in the Experimental Lakes Area of northwestern Ontario. Information on the background chemistry, acidification and initial results can be found in Schindler (1980), Schindler et al. (1980), Schindler and Turner (1982) and Mills (1984). The pre-acidification pH range of 6.5-6.7 in 1976 was lowered at a rate of ≈0.25 pH units per year to a pH range of 5.0-5.2 in 1981 and was held at this value in 1982 and 1983 (Cruikshank 1984). Data presented in this report were collected from September, 1975, to November, 1983.

White suckers were sampled throughout the ice-free season, usually late April until late October. Two methods of capture were used: modified versions of Beamish trap nets (Beamish 1972) and small mesh multifilament gillnets (bar mesh 25-45 mm). Fish captured by trap net were sampled immediately after being removed from the trap net. Those captured by gillnet were held overnight prior to being sampled, to assess gill-net sampling mortality.

Fish were anaesthetized with tricaine methane sulfonate (MS222®), sampled, allowed to recover and released. The following data were collected for each fish: fork length (to the nearest mm), weight (to the nearest g), sex (if possible), and previous capture history as determined by tag number and/or fin scarrings. Fish with fork lengths greater than 280 mm were tagged with modified Carlin tags (White and Beamish 1972); fish smaller than this were not tagged. All fish were batch-marked according to sampling period by scarring dorsal or anal fin rays (Welch and Mills 1981). Two or three rays of a pectoral fin were removed for age determination when fish were captured for the first time. Recaptured fish had two or three rays removed from an unclipped pectoral or pelvic fin if the time elapsed since last sampling was at least one year.

Fin rays were air-dried in envelopes, fixed in epoxy and sectioned with a fine-toothed jeweller's saw. Sections were mounted on microscope slides according to methods described by Beamish (1973). The fin-ray method for aging the Lake 223 population of white suckers was previously validated, and further details on the aging technique used in this study can be found in Chalanchuk (1984).

Seasonal length-frequency distributions were based on fork lengths. From 1977 - 1980, fish with fork lengths less than 150 mm were subsampled; the rest of the fish in this length category were counted and measured, but were not marked. Only the subsampled fish were included in the length-frequency graphs. Before 1977 and after 1980, all fish were counted, measured and marked. These fish were, therefore, included in the length-frequency graphs.

A composite age frequency distribution for 1976 was constructed by subtracting the appropriate number of years from the ages of individual fish captured after 1976 to determine their ages in 1976. For example, a fish aged eight years when caught in 1982 would have been two years of age in 1976. All fish captured for the first time during 1977-1981 were included in the composite age-frequency distribution. This distribution was constructed to illustrate population trends with time in an effort to determine year-class failures during the experimental years and before acidification of Lake 223.

Growth curves were constructed by plotting mean fork lengths at age and mean weights at age for the spring sampling periods each year. Composite growth curves for all years were fitted by eye.

Back-calculations of lengths for 255 fish were done to determine growth of suckers for two to five years before acidification of Lake 223

because there was very little data for fish during this time period. A geometric mean (GM) functional regression of fork-length against fin-ray length was used. Ricker (1973) recommended the use of the GM regression for back-calculations of length because measurements of errors of x and y variables are minor relative to natural variability. The back-calculation formula of Bagenal and Tesch (1978) was used:

$$L_i - a = l_i/l\ (L - a)$$

where L_i = fork length of fish at time i
L = total fork length of fish when fin was obtained
l_i = radius of ray at time i
l = total radius of ray when fin was obtained
a = intercept from regression.

Calculated lengths were then used to construct growth curves for individual years from 1971-1975.

Condition was determined using Fulton's condition factor (Bagenal and Tesch 1978):

$$K = \frac{100}{l^3} w$$

where w = observed weight of fish (g)
l = observed length of fish (cm).

Condition factors were calculated on a seasonal basis for nine fork-length intervals. Means of all the length groups for each season were determined and were plotted for all years. Seasonal intervals were: spring (April to June), summer (July to August) and fall (September to early November).

RESULTS AND DISCUSSION

RECRUITMENT

Recruitment failure is an important mechanism in the loss of fish populations (Jensen and Snekvik 1972; Beamish et al. 1975; Schofield 1976). Trojnar (1977) demonstrated an increase in deformities and a lack of successful swim-up of sucker prolarvae at pH 5.02. Although the pH of Lake 223 was lowered to 5.0-5.2 by 1981 (Cruikshank 1984), physical deformities of fish were not observed. In fact, physical deformities were not observed throughout the entire study period. In contrast, recruitment failures did occur when the pH decreased to these low values.

Recruitment failures in Lake 223 began in 1981. These were indicated by the absence of fish with fork lengths less than 150 mm (age 0+ and age 1+) caught in 1982 and 1983 (Fig. 1a and 1b). In contrast, large numbers of fish in this length category were caught from the spring of 1978 until the spring of 1981, indicating successful recruitment during this time period. Only small numbers of young fish were caught before spring 1978. However, sample sizes in 1976 and 1977 were usually very low, whereas, in 1982 and 1983, sample sizes were usually very much higher (as much as 10-15 times higher in some cases). Despite these higher sample sizes, and increased fishing effort, in comparison to that which occurred before 1978, essentially no young-of-the-year and age 1+ fish were caught in 1982 and 1983. The exclusive use of gillnets in 1975 was responsible for the absence of young fish during during this time period. Fish with fork lengths less than 150 mm were not captured by gillnet throughout the entire study period.

Recruitment failures in 1981, 1982 and 1983 were confirmed by comparisons of numbers of young-of-the-year fish collected in Lake 223 from June to October during 1977-1983 (Fig. 2). These fish were not included in the length-frequencies in Fig. 1a and 1b but are in addition to numbers represented there. Fishing gear and techniques used during 1981-1983 were the same as those used before 1981. Fishing effort was somewhat greater during most of 1981-1983 and one would expect higher catches than before 1981. Sampling biases did not, therefore, cause the differences between years in numbers of young-of-the-year fish captured.

A composite age frequency distribution (Fig. 3) provided further confirmation of recruitment before 1977. Good recruitment occurred in 1972, 1973 and 1975. Less successful recruitment was shown by the 1971, 1974 and 1976 year-classes. Low numbers of fish in year classes prior to 1967 were due to natural mortalities of older fish. The pH of Lake 223 was probably greater than 6.5 during this entire period (a pH of 7.0 in 1973 was reported by Beamish et al. (1976)). Despite fluctuations in strength of year classes and the presence of poor year classes, it is evident that no recruitment failures occurred in any year from 1964-1976.

The occurrence of recruitment failures in Lake 223 during only 1981-1983 and at no other time from 1964-1980 suggests that they were caused by decreases in pH and not by natural population cycles. Data from Lake 302, a control lake with a pH > 6.25 from 1973-1982 (Beamish 1976; Cruikshank 1984), indicate that recruitment occurred throughout this time period, including during 1981 and 1982. Also, there were no indications of year-class failures from 1981-1983 in other unmanipulated lakes in the area (K.H. Mills, Freshwater Institute, Winnipeg, Manitoba, personal communication).

GROWTH

Growth of fish has been shown to increase (Ryan and Harvey 1977) and to decrease (Beamish et al. 1975) in acidified lakes. Ryan and Harvey (1977) found that growth rates of younger-aged rock bass, Ambloplites rupestris, were faster in more acid lakes, probably because of lower population densities caused by reproductive failures. Beamish (1974), on the other hand, noted a decrease in growth of suckers in an acidified lake compared to that present when the lake was at a higher pH. This decrease in growth occurred despite an adequate food source and was followed by mortality of larger indivi-

duals. In Lake 223, growth rates of younger fish increased as pH decreased, while growth rates of older fish remained fairly constant.

Fish aged two to six years grew faster in length during 1980-1982 than did comparably aged fish during 1976-1978 (Fig. 4) and during 1971-1975 (Fig. 5). Error bars were very small for this age-group (Fig. 6a and 6b) and growth curves could be directly compared. Pre-acidification growth rates of young suckers in Lake 223 were similar to or lower than rates during acidification, especially during 1980-1982. Harvey and Lee (1981) found that younger fish had greater lengths at age in two acid lakes studied than did correspondingly aged fish in two non-acid lakes. No change in growth rates of younger fish occurred in non-acid Lake 302 during 1976-1982.

Fish older than six years of age grew at similar rates throughout the 1971-1982 period (Fig. 4 and Fig. 5). Error bars were quite large because of low sample sizes, and overlapped for the older fish. Maximum lengths attained by white suckers were similar between years. Similar trends were shown by growth curves based on weights (Fig. 7a and 7b).

The growth rate of Lake 223 suckers in 1976 was near the middle of the range of growth for white suckers (as reported by Beamish (1973)) (Fig. 4). During 1980-1982 growth rates of fish aged two to six years approached the extreme upper limit of growth. This was the only time during 1971-1982 that growth rates were near the upper limits (Fig. 5); most years, they were near the middle of the range or lower.

In Lake 223, changes from the rapid growth of young fish to the slower growth of older fish were correlated with sexual maturity. In most fishes growth decreases after the onset of sexual maturity (Brown 1957). Onset of sexual maturity in Lake 223 occured at two years for males and three or four years for females. However, most fish this young were still sexually immature. Spoor (1938) noted that the average age of maturity was approximately two years later than the onset of maturity in a population of white suckers in Muskellunge Lake, Wisconsin. Males generally matured one or two years earlier than females in both Muskellunge Lake and in Lake 223. Most males in Lake 223 were mature by five years of age; most females were mature by seven years. This is coincident with the decrease in growth rates around the age of six years.

Females appeared to grow faster than males during 1978-1979, but grew at similar rates up to the age of four or five years of age during 1980-1982 (Fig. 8a and 8b). The precision of some age-at-length estimates was poor because of small sample sizes, especially for females and for older fish in general. Females older than five years of age were generally longer and heavier than males of the same age. This difference was also noted by Spoor (1938) in Muskellunge Lake suckers. According to Hauser (1969), females of all species of the genus Catostomus were generally longer than males of the same age. The age at which the change in growth rates occurred correlated well with sexual maturity as discussed previously.

Although the initial response of white suckers to decreased pH in Lake 223 was increased growth of young fish, a slight decrease in growth rates may have occurred in 1982. It is unclear whether this was a somewhat poorer growth year or was the beginning of a decline in growth because of acidification or of density-dependant factors. Wiener and Hanneman (1982) showed an inverse correlation between growth rates and densities of populations of bluegills, Lepomis machrochirus, in acidic lakes in Wisconsin. The Lake 223 white sucker population peaked in abundance in 1981 (K.H. Mills,personal communication), then declined. Dipteran populations, which provided the major food source for the white suckers, also increased in biomass and numbers (peaking in 1979 and 1980, respectively) (I.J. Davies, Freshwater Institute, Winnipeg, Manitoba, personal communication). They declined during 1981-1983, either as a result of acidification or of predation by the increased numbers of suckers. This decline may then have caused the beginning of a decline in growth of white suckers. No change in growth rates occurred in Lake 302, the control lake, during 1976-1982.

CONDITION

Condition factors are used to indicate fish's "well-being" or "fatness" (Bagenal and Tesch 1978). They are especially useful when comparing the same populations over several years.

Condition factors of white suckers in Lake 223 increased during the early acidification years, but then declined as pH decreased to even lower values. Before 1979, there was greater seasonal variability between condition factors; after 1980, condition factors remained at fairly constant values (Fig. 9a). Within individual years, condition factors were usually lower during summer than during spring or fall. Fish caught during the summer had completed spawning but had not accumulated much new gonadal material so were less "fat" than fish caught in the spring. Also, they were in the middle of their growth season so were not as "fat" as fish caught in the fall after a complete growing season. Smaller sample sizes during summer and fall, especially prior to 1980, caused greater variability. Consequently, spring values of condition factor were more useful in denoting population trends.

Condition factors increased from 1976 to a peak in 1978 (Fig. 9b). Harvey and Lee (1981) noted higher condition factors for white suckers in acid Chub Lake, compared to factors in three other populations studied. Two of these three lakes were non-acid. Condition factors for Lake 302 were also similar to values for these non-acidic lakes and lower than values for Lake 223. In 1979, condition factors in Lake 223 decreased. In 1982 and 1983, values were lower than in any other year from 1976-1981. The highest mean spring condition factor for each fork-length group occurred during 1977-1979

(Table 1). Lowest condition factors for fish with fork lengths greater than 150 mm occurred in 1982 or 1983. Condition factors for fish smaller than this fluctuated more from year to year, but values in 1982 and 1983 were, nonetheless, all lower than in 1978. The general trend, therefore, was a slight decline in condition of Lake 223 suckers from 1979-1983.

SUMMARY

Increasing acidification of Lake 223 was the probable cause of recruitment failures that occurred in the white sucker population in 1981, 1982 and 1983. No failures in recruitment occurred in Lake 223 in any other year from 1971-1980 and none occurred in other non-acidic lakes in the Experimental Lakes Area from 1971-1983. Increases in growth and in condition during the early years of acidification were made possible by increases in the dipteran food supply. An increase in numbers of white suckers in the population occurred simultaneously. This led to a decline in condition factors, followed by a decline in growth as the food supply decreased. By 1982, condition factors were lower than during any other year prior to 1982, and growth seemed to be beginning to decline. These decreases in growth and condition, combined with the recruitment failures of Lake 223 white suckers, suggest that the population is stressed. A poor future for the Lake 223 white sucker population is very likely if the pH remains at a value of 5.0 or less.

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Table 1. Mean condition factors ± 95% confidence limits at annual spring intervals from 1976-1983 for nine fork-length groups. Numbers in parentheses are sample sizes.

Fork length (mm)	Spring 1976	Spring 1977	Spring 1978	Spring 1979	Spring 1980	Spring 1981	Spring 1983	Spring 1983
51-100			1.52±0.06 (68)	1.10±0.04 (99)	1.15±0.05 (97)	1.09±0.04 (91)	1.40±0.00 (1)	
101-150		1.04±0.06 (26)	1.39±0.29 (4)	1.16±0.04 (38)	1.22+0.04 (59)	1.23±0.19 (68)	1.27±0.62 (2)	
151-200	1.29±0.02 (51)	1.31±0.03 (35)	1.25±0.03 (47)	1.29±0.08 (8)	1.25±0.01 (408)	1.24±0.01 (1617)	1.22±0.04 (40)	1.28±0.99 (2)
201-250	1.26±0.01 (287)	1.32±0.05 (21)	1.30±0.02 (73)	1.30±0.01 (155)	1.28±0.01 (377)	1.28±0.01 (424)	1.24±0.01 (616)	1.26±0.06 (73)
251-300	1.32±0.01 (180)	1.38±0.03 (24)	1.45±0.06 (7)	1.45±0.02 (53)	1.44±0.04 (9)	1.34±0.01 (1050)	1.26±0.01 (956)	1.22±0.01 (820)
301-350	1.38±0.18 (22)	1.50±0.06 (10)	1.49±0.05 (15)	1.49±0.03 (86)	1.45±0.01 (169)	1.37±0.01 (314)	1.29±0.01 (484)	1.25±0.01 (713)
351-400	1.47±0.08 (11)	1.46±0.05 (15)	1.51±0.06 (14)	1.64±0.11 (9)	1.49±0.02 (115)	1.46±0.01 (210)	1.31±0.01 (205)	1.28±0.02 (195)
401-450	1.49±0.12 (11)	1.49±0.08 (13)	1.43±0.05 (16)	1.58±0.06 (8)	1.50±0.11 (25)	1.46±0.02 (88)	1.35±0.02 (79)	1.20±0.07 (38)
451-500	1.37±0.30 (4)	1.35±0.00 (1)	1.51±0.61 (2)	1.45±0.00 (1)	1.51±0.08 (4)	1.49±0.05 (3)	1.39±0.00 (1)	1.25±0.00 (1)
overall mean	1.30±0.01 (566)	1.32±0.03 (145)	1.39±0.02 (246)	1.31±0.02 (457)	1.31±0.01 (1263)	1.29±0.01 (3865)	1.27±0.00 (2384)	1.24±0.01 (1834)

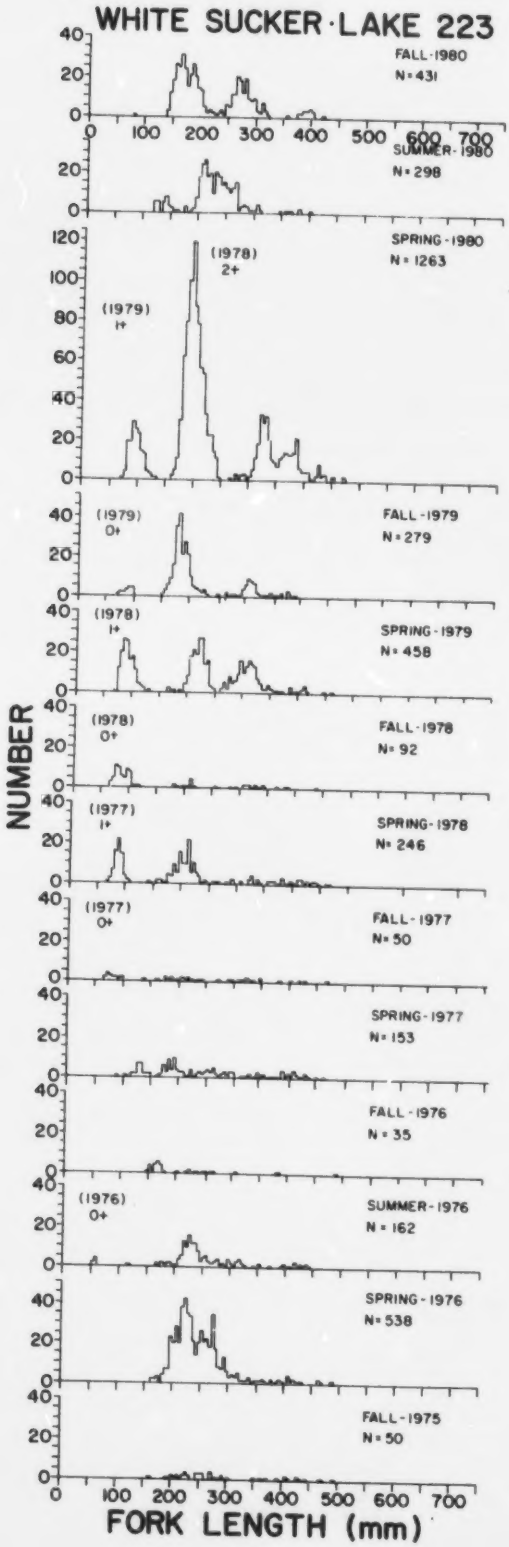

Fig. 1a. Length-frequency histograms on a seasonal basis from fall 1975 until fall 1980. Numbers beside peaks represent year-classes and ages.

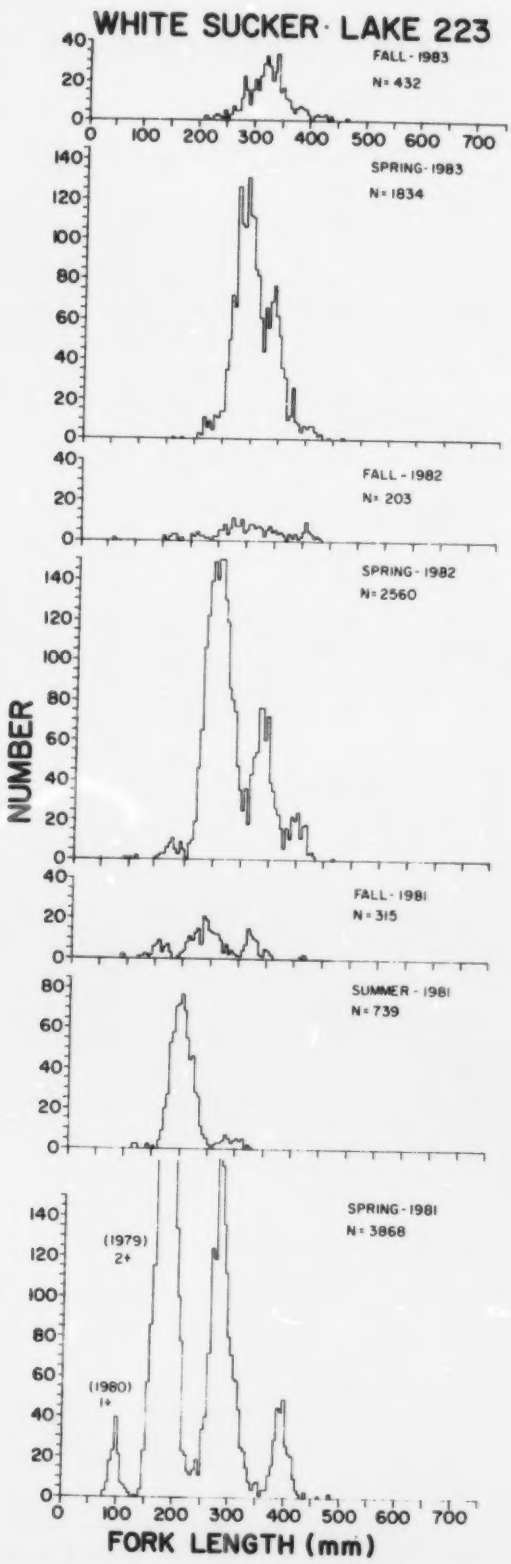

Fig. 1b. Length-frequency histograms on a seasonal basis from spring 1981 until fall 1983. Numbers beside peaks represent year-classes and ages.

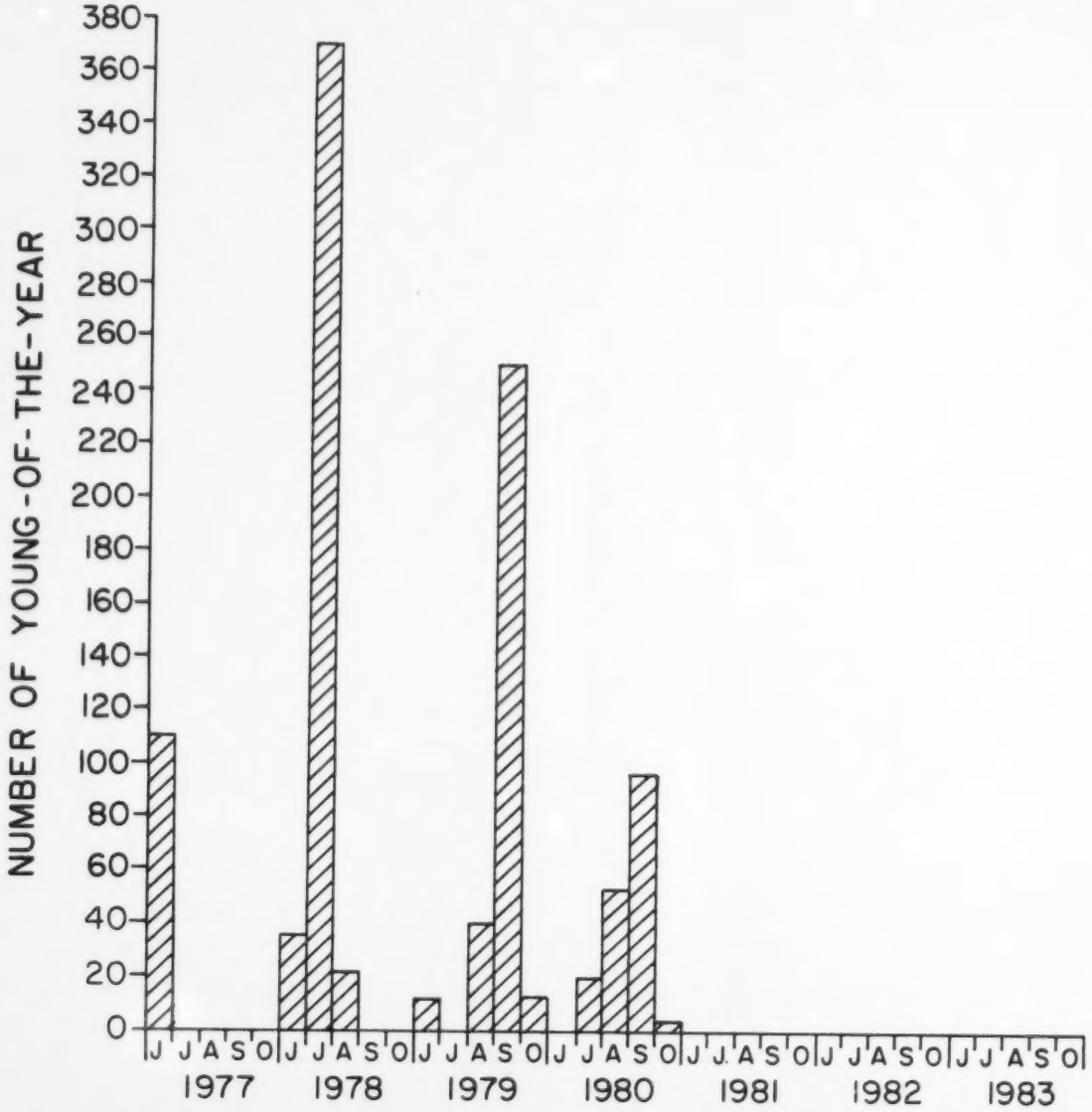

Fig. 2. Numbers of young-of-the-year white suckers captured on a monthly basis (June-October) from 1977 until 1983.

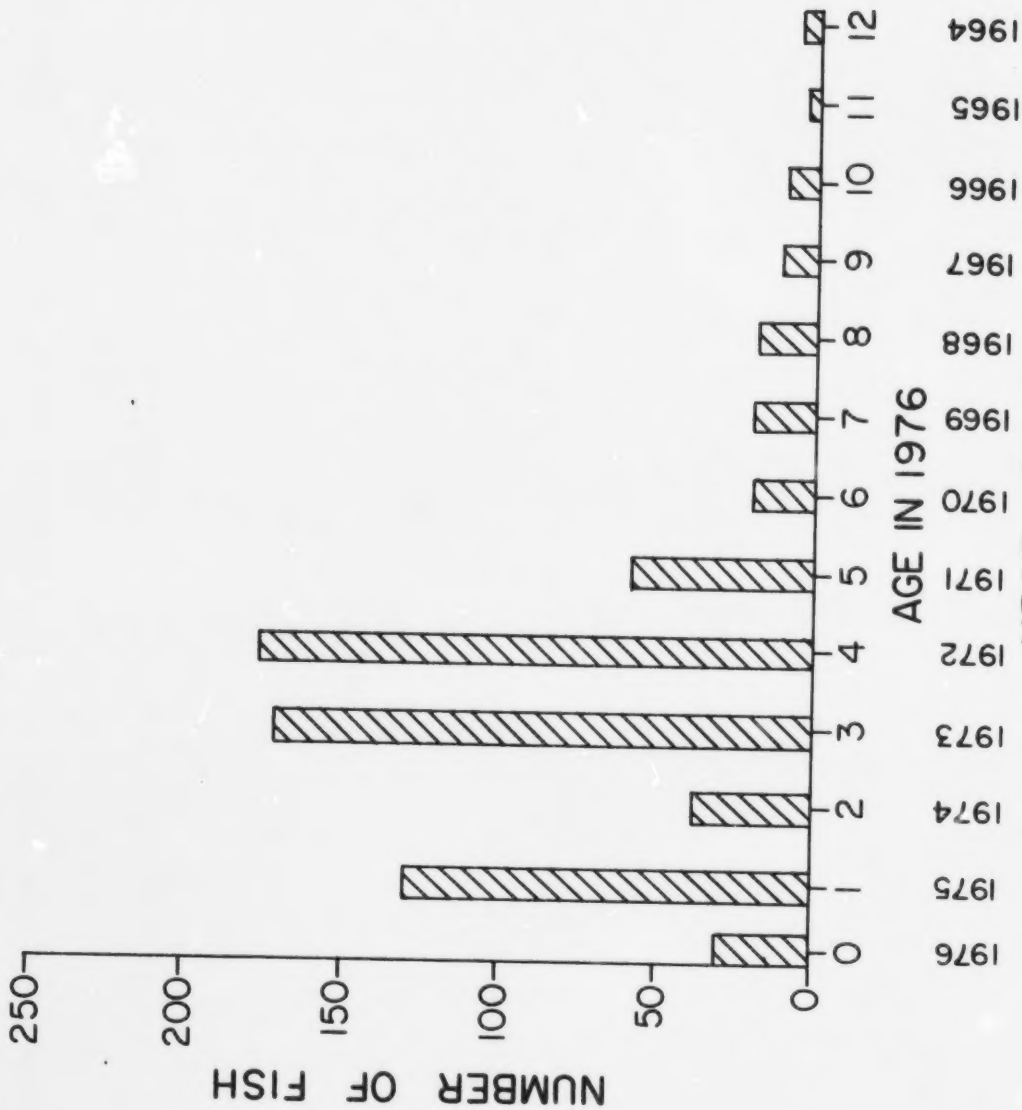

Fig. 3. Composite age-frequency histogram for 1976, showing corresponding year-classes.

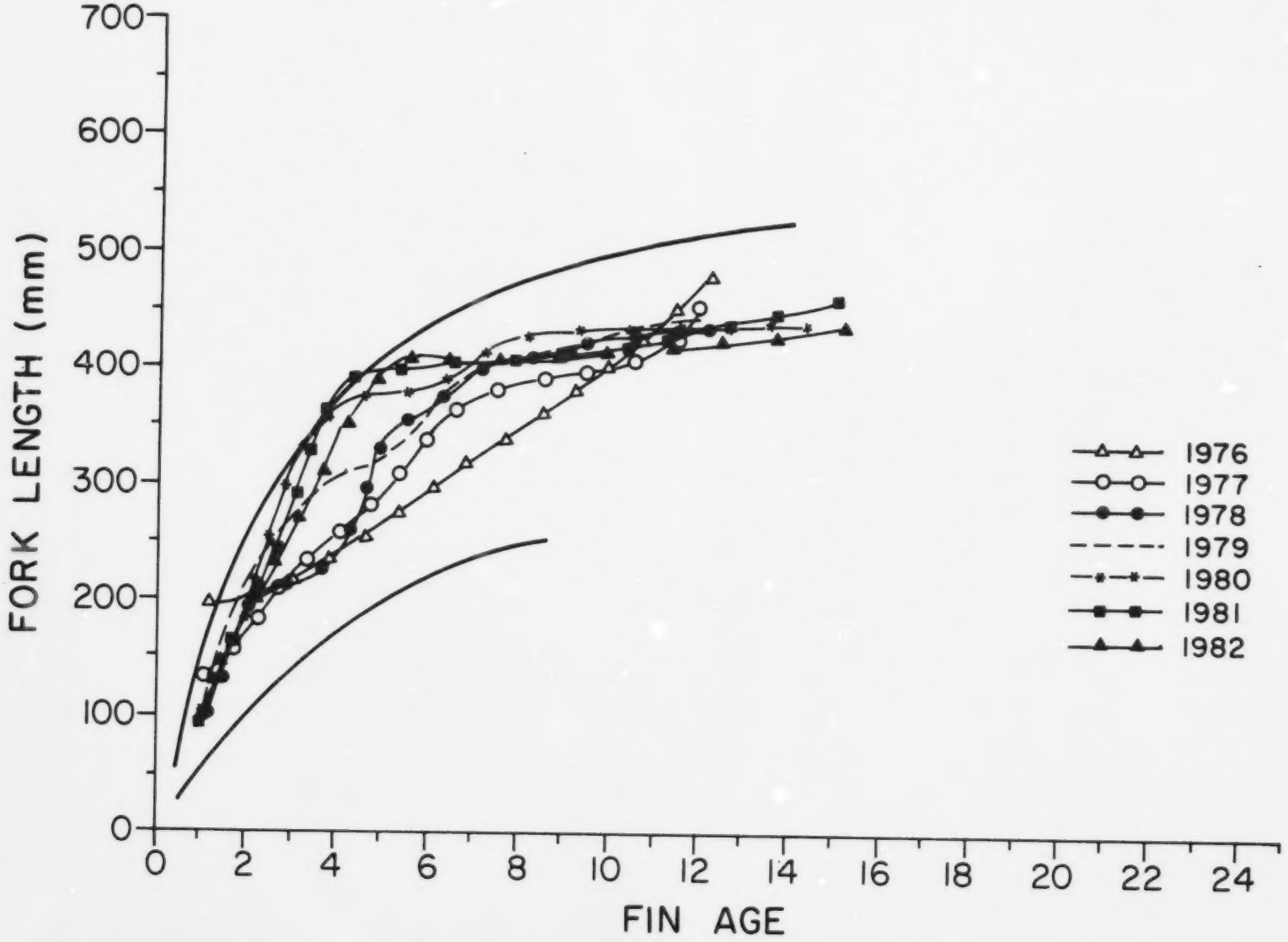

Fig. 4. Summary of growth curves, based on fork lengths, at annual spring intervals. Solid black lines indicate limits of range of growth as taken from Reamish (1973) Fig. 7.

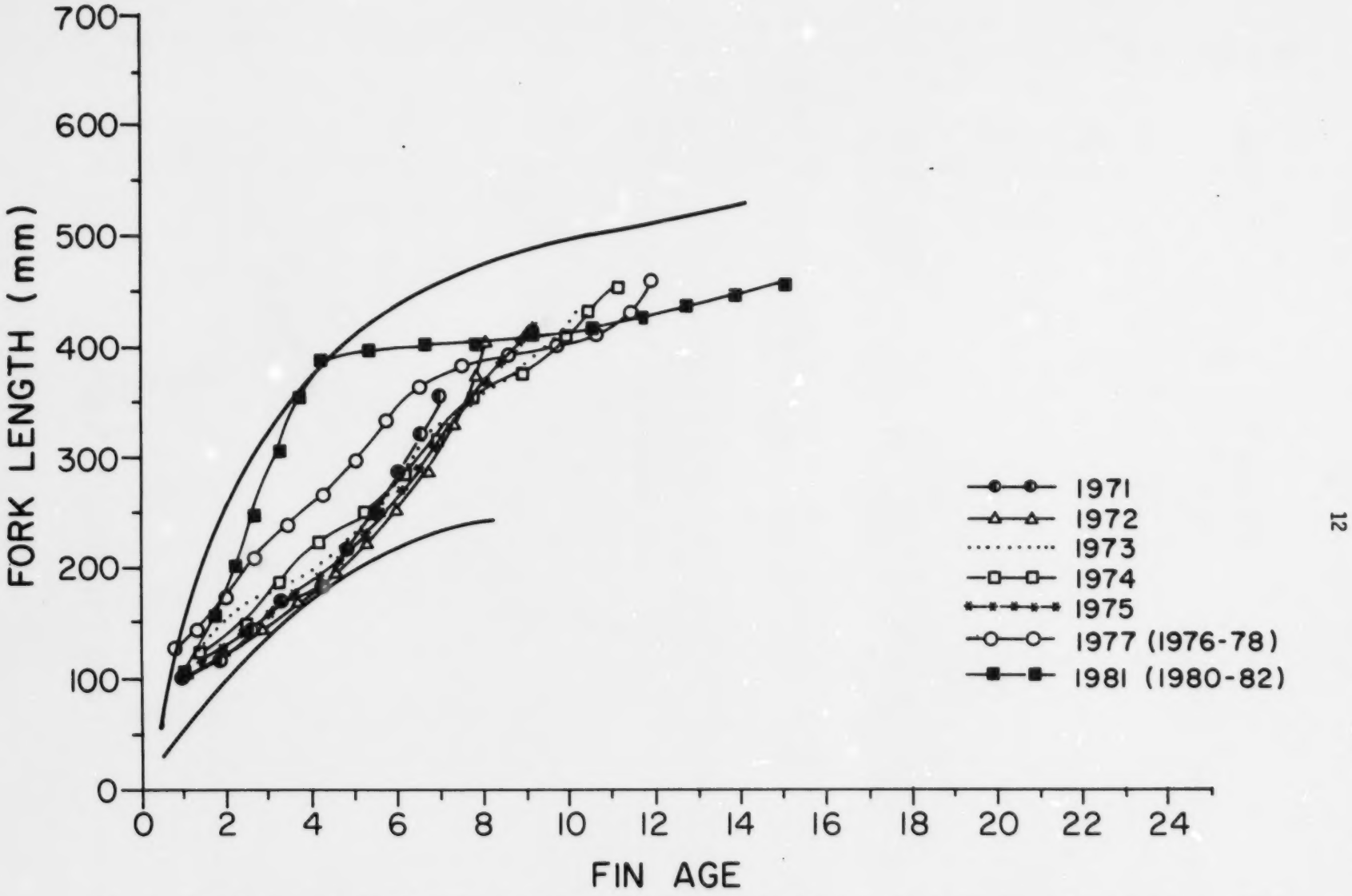

Fig. 5. Growth curves, based on back-calculated fork-lengths, at annual spring intervals from 1971 until 1975 compared to growth rates since 1976. The growth curve from 1977 was chosen to represent the 1976-1978 period; the growth curve from 1981 was chosen to represent the 1980-1982 period. Solid black lines indicate the limits of range of growth as taken from Beamish (1973) Fig. 7.

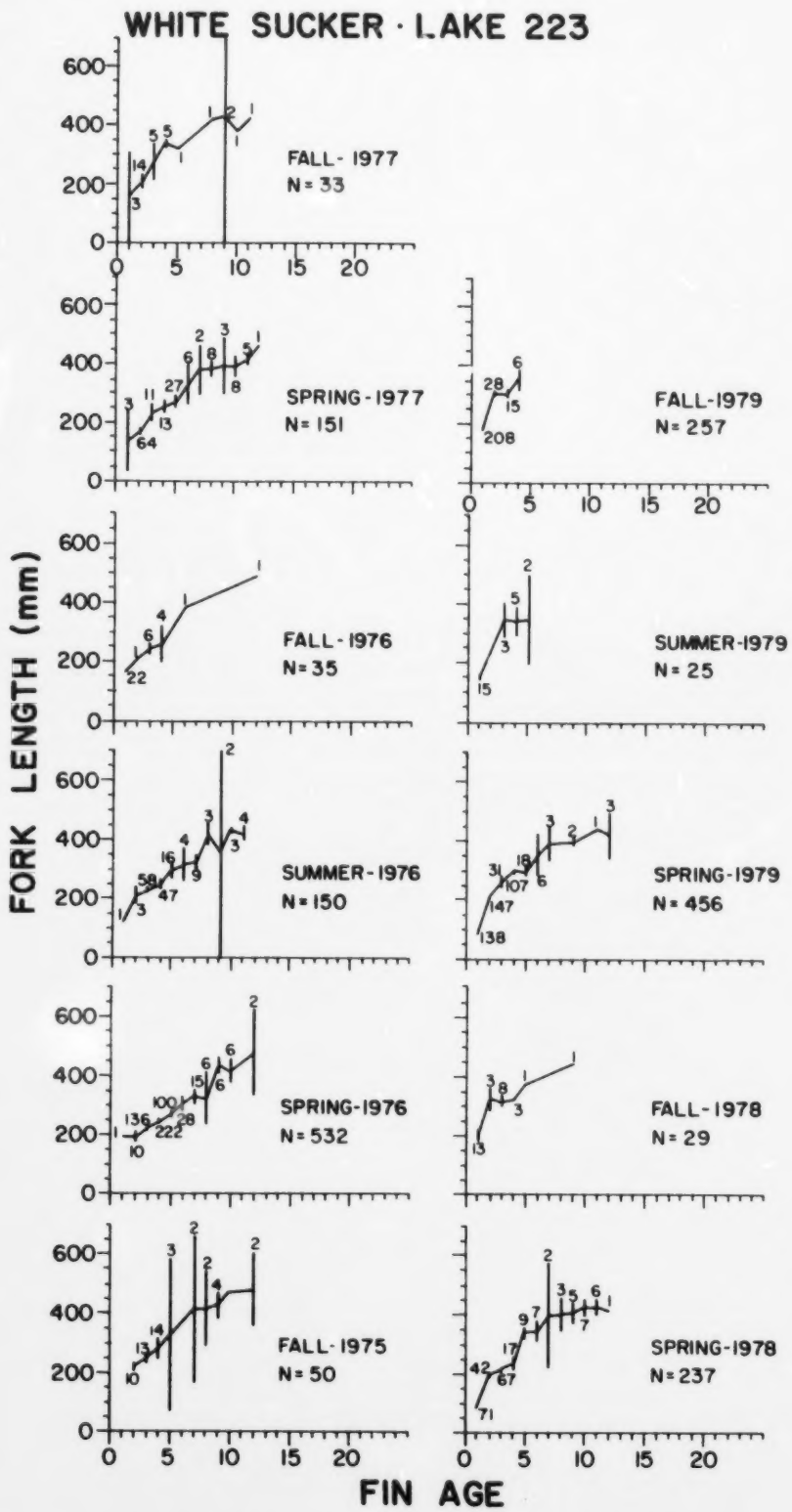

Fig. 6a. Growth curves of white suckers, based on fork lengths, on a seasonal basis from fall 1975 until fall 1979. Error bars show 95% confidence limits. Numbers beside points indicate sample sizes.

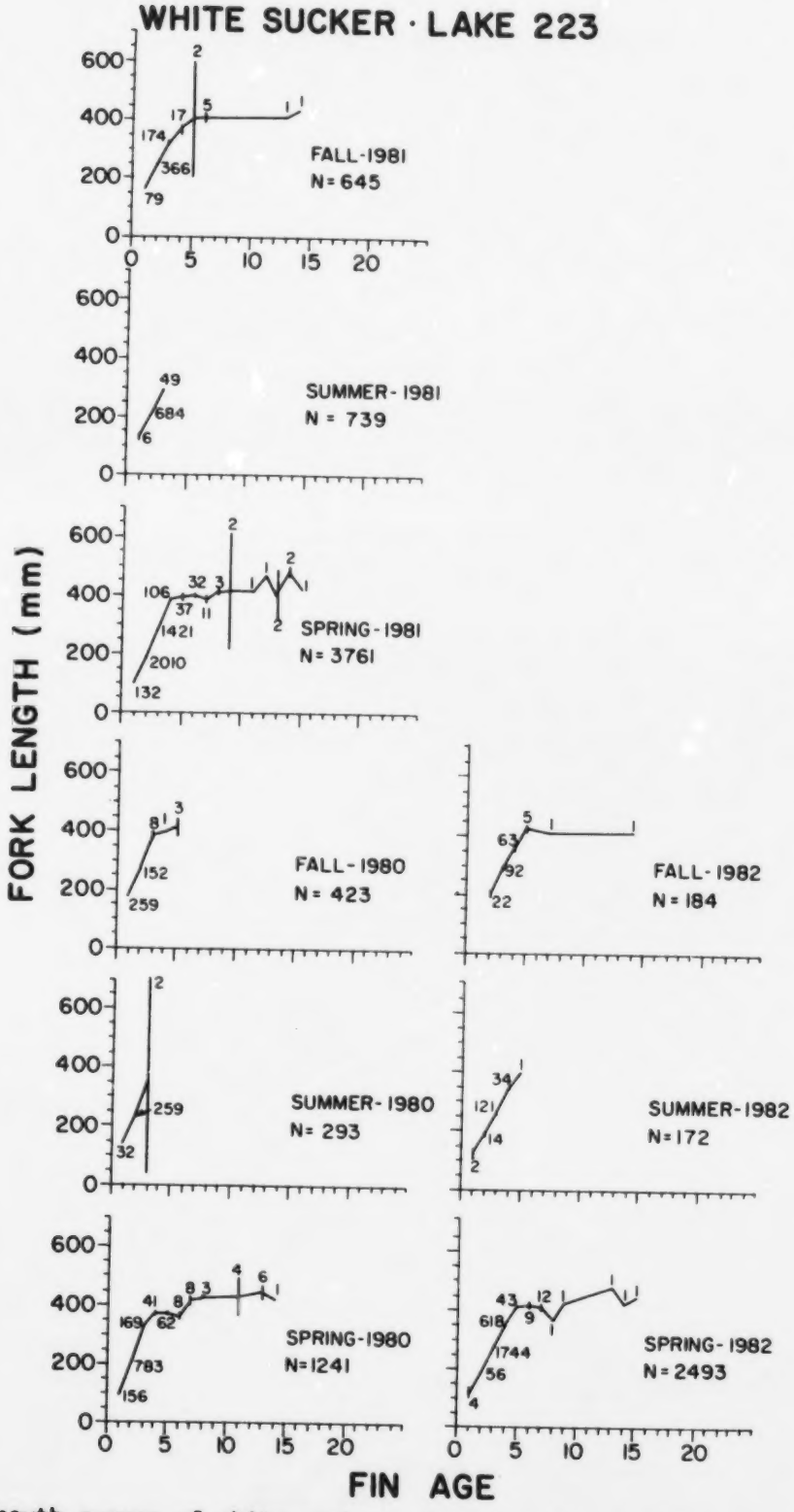

Fig. 6b. Growth curves of white suckers, based on fork lengths, on a seasonal basis from spring 1980 until fall 1982. Error bars shows 95% confidence limits. Numbers beside points indicate sample sizes.

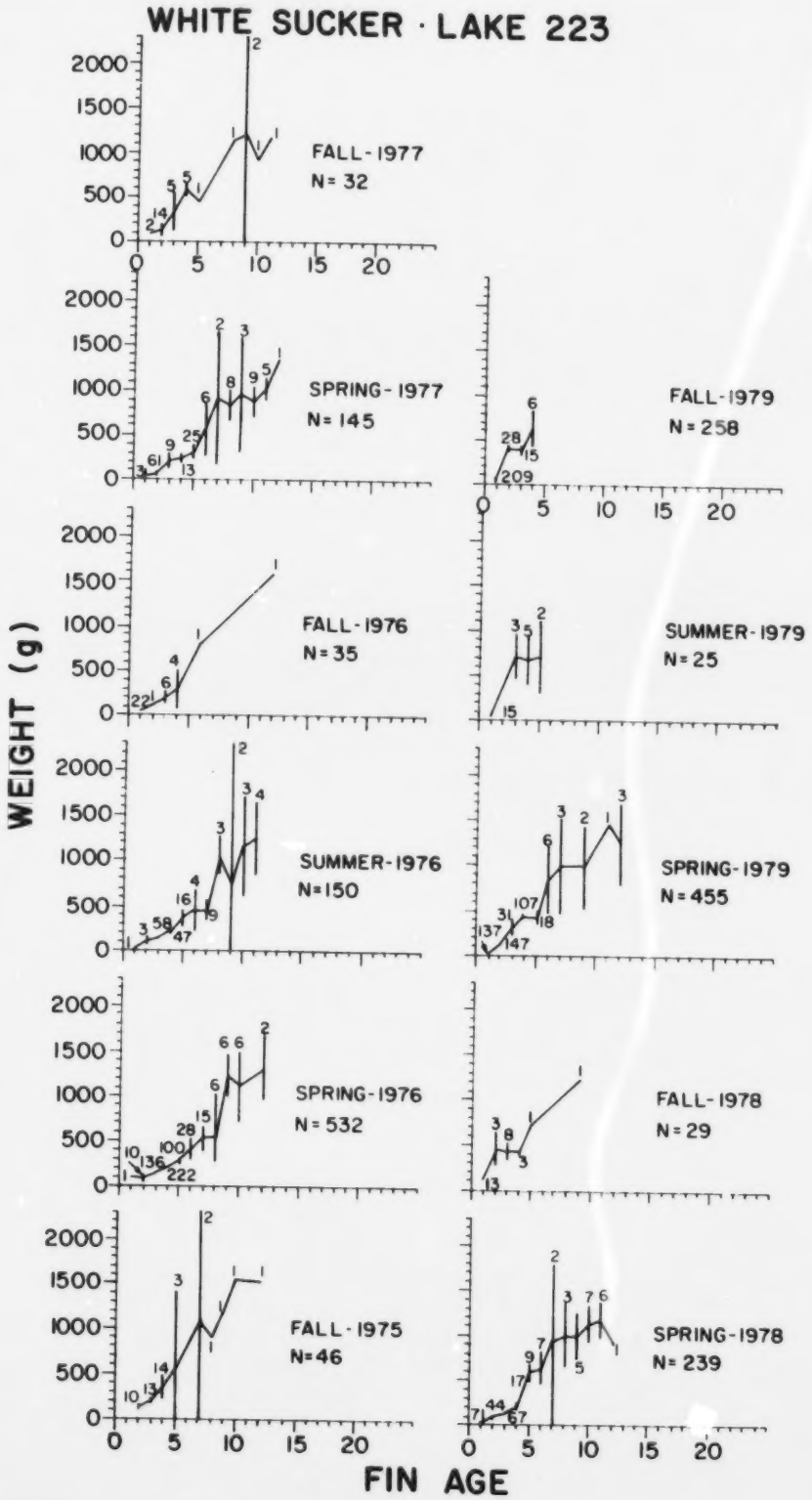

Fig. 7a. Growth curves of white suckers, based on weights, on a seasonal basis from fall 1975 until fall 1979. Error bars show 95% confidence limits. Numbers beside points indicate sample sizes.

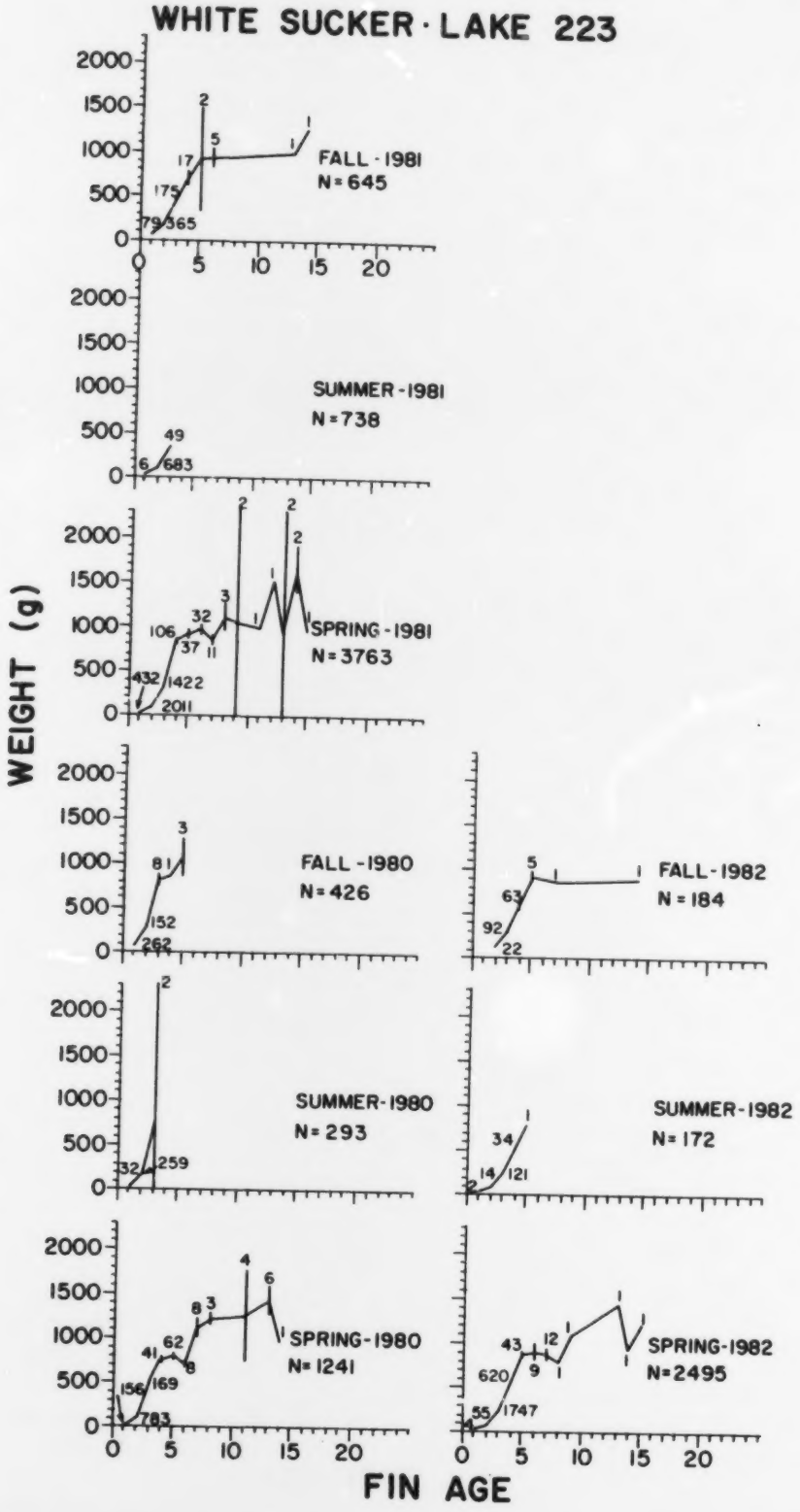

Fig. 7b. Growth curves of white suckers, based on weights, on a seasonal basis from spring 1980 until fall 1982. Error bars show 95% confidence limits. Numbers beside points indicate sample sizes.

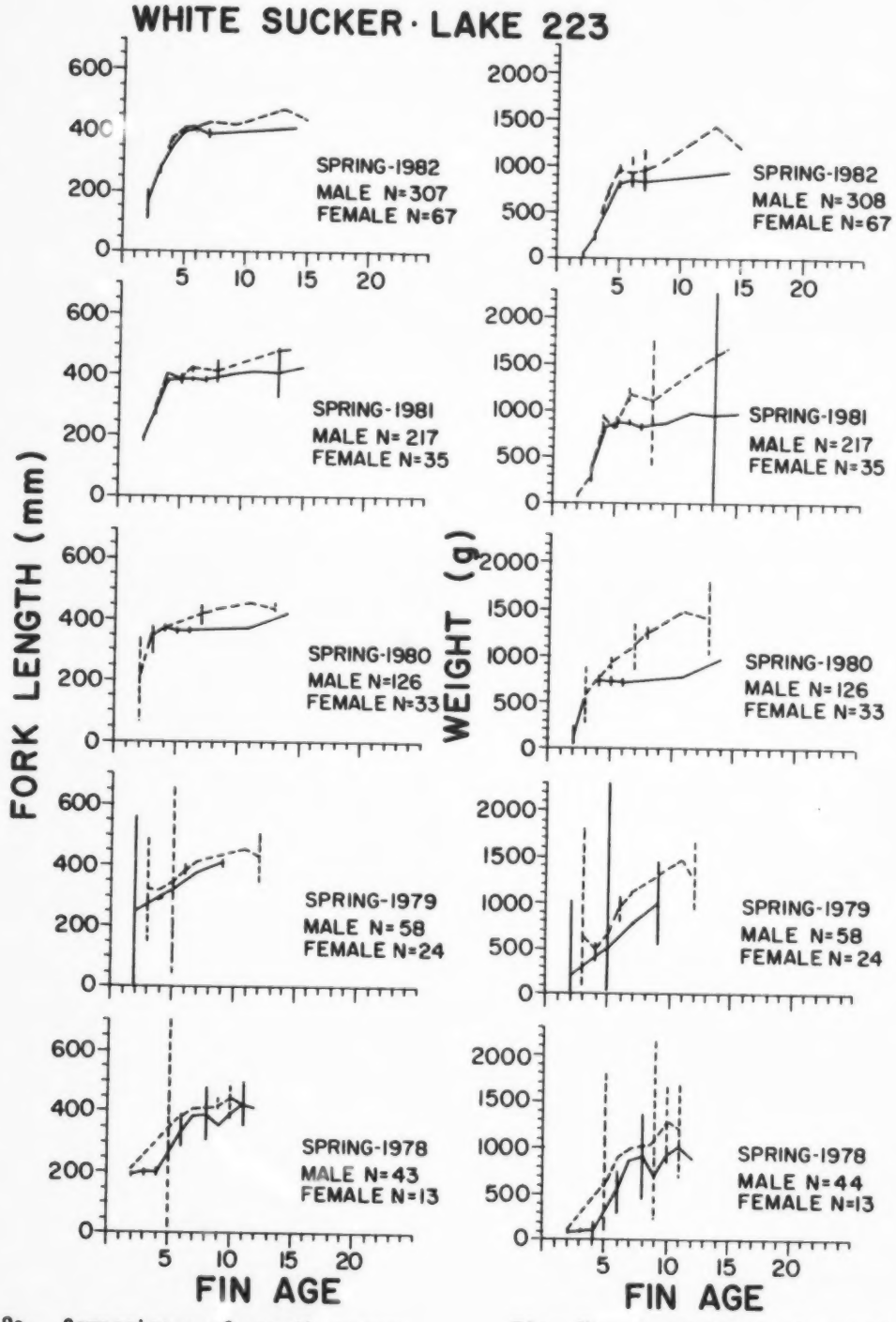

Fig. 8a. Comparisons of growth curves, based on fork lengths, for males and for females at annual spring intervals from spring 1978 until spring 1982. Error bars show 95% confidence limits. Dotted lines represent females, solid lines lines represent males.

Fig. 8b. Comparisons of growth curves, based on weights, for males and for females at annual spring intervals from spring 1978 until spring 1982. Error bars show 95% confidence limits. Dotted lines represent females, solid lines lines represent males.

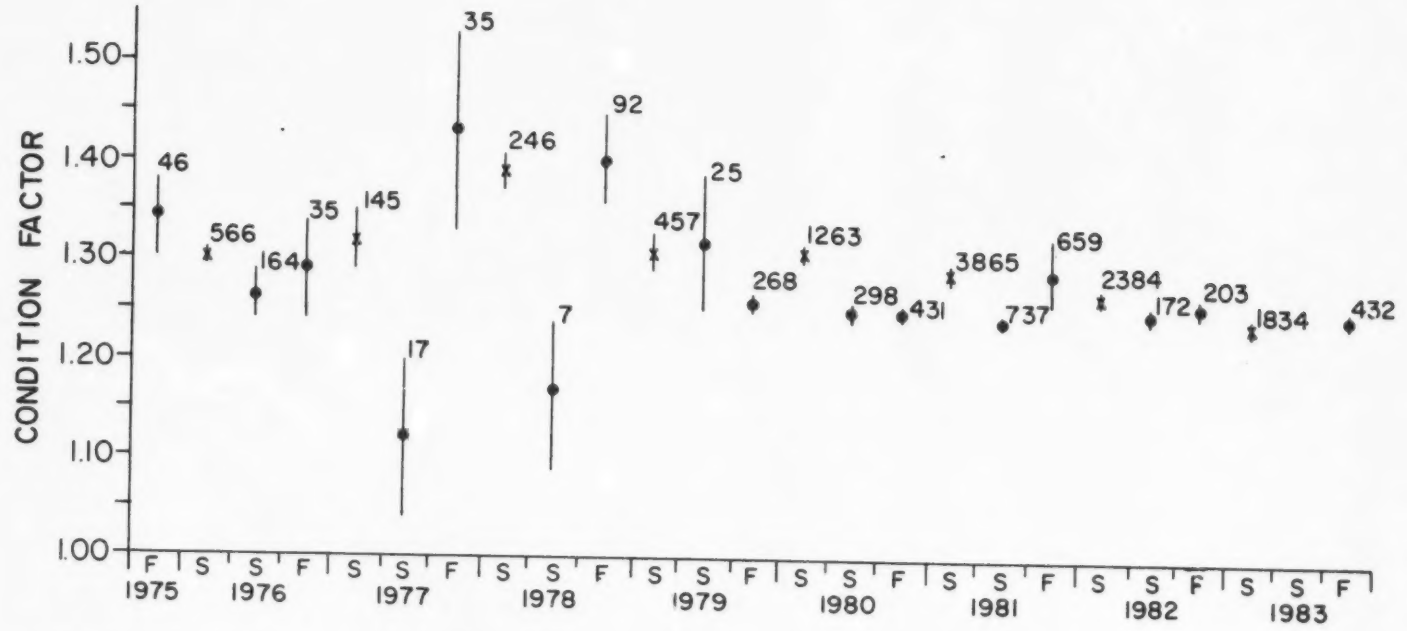

Fig. 9a. Condition factors of white suckers at seasonal intervals from fall 1975 until fall 1982. Error bars show 95% confidence limits. Numbers beside points are sample sizes.

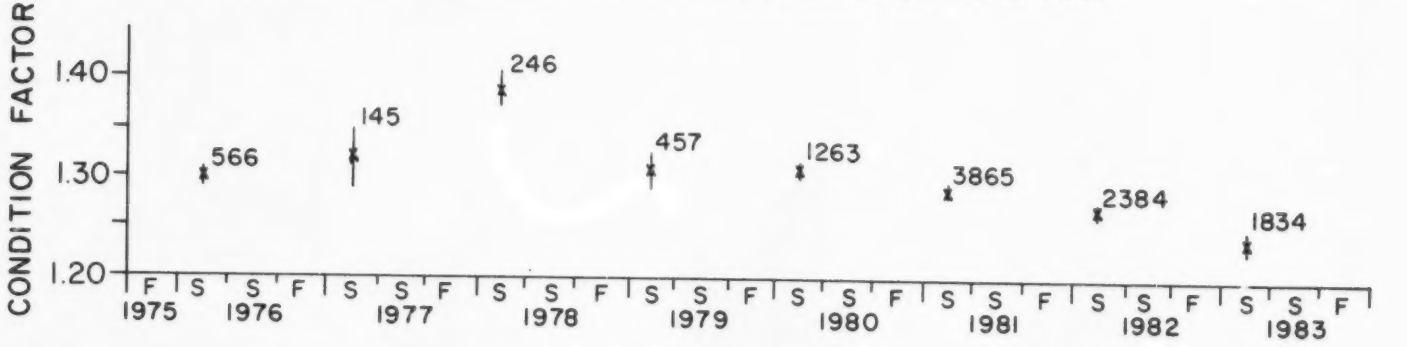

Fig. 9b. Condition factors of white suckers at spring intervals from 1976 until 1983. Error bars show 95% confidence limits. Numbers beside points are sample sizes.